CONTRIBUTIONS FROM GEOGRAPHY TO URBAN TRANSPORTATION RESEARCH

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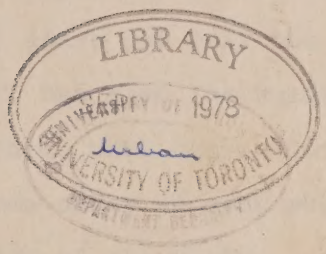

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* Seattle's status as the chief centre in the Pacific Northwest, and its relation to the lesser centres in Washington, Oregon, and Idaho, and to the Canadian city of Vancouver.

* The effect of the mountain barrier that separates it from the bulk of the United States, and from most of its own state of Washington, too.

* Its dependence on hydro-electric power from the Columbia and Snake Rivers, and the effect of negotiations with Canada on the availability of additional power.

* Its special relation to Alaska.

* Its role as a world port on the Pacific, and the competition for its hinterland offered by Los Angeles, San Francisco, Portland, Vancouver, and even Prince Rupert (the last for the Alaska trade.)

By design, the above list has almost nothing to say about the one factor that must be considered above all others: people, their social needs, their aesthetic likes and dislikes, their individual reasons for living in the city and moving about and beyond it. These excluded questions are the domain of the sociologist and the architect, whose skills have been recognized as essential to the solution of the urban transportation problem. The one characteristic that the items included in the list have in common is that, in one way or another, they involve relations between places distributed on the earth's surface. To that extent, they are all in the domain of the geographer.

In the present paper we shall briefly examine the field of geography and the specific contributions it has made to an understanding of the urban transportation problem.

So brief a survey of so broad a subject can provide few substantive details, nor are such details altogether essential in a paper that is intended merely to put on the record

the work that geographers have done, in a place where it will be available to researchers from other disciplines in the field of urban transportation. Reference will be made to a wide range of representative studies, and those who wish to delve deeper will find, in the appendix, a short list of bibliographic and review articles that will help them locate other reports in their field of special interest.

The Field of Geography.

To begin with, it must be emphasized that geography does not have a subject matter exclusively its own. What is unique to geography is its point of view, and nothing else. It is an integrative discipline; it tries to bring together all the phenomena that find an areal expression on the earth's surface, to discover and classify any uniformities that exist, and to clarify the causal relations between phenomena. In so doing geography draws upon a host of other disciplines for their special insights, thereby gaining a synoptic view of the problems that it examines.

As with other disciplines, so with geography, there is no universally agreed upon definition of the limits of the field. Engineers are familiar with the dictum: "Engineering is what engineers do." Similarly we are told: "Geography is what geographers do." It does little good to define engineering in this way to geographers, or geography to engineers. But an example from each may help to clarify at least some of the distinctions between the disciplines.

In Figs. 1 and 2 are presented two flow plans; the first shows the flow of motor traffic on highways in a highly urban-

ized area, and the second, the flow of certain goods between one specific area in the United States and all others. The engineer uses maps such as that in Fig. 1 to learn how much traffic each road in the area is expected to carry, so that he may make such changes in the road system as are necessary to allow the system as a whole to work efficiently; the geographer uses maps such as those in Fig. 2 to learn something about the spatial interactions between the area under study and other areas. There is a very important distinction here, the distinction between the engineer's primary interest in the facilities for movement and the geographer's primary interest in the areas between which movement takes place.

Engineers will notice other differences between their ways of dealing with the problems of urban transportation and those of geographers, particularly academic geographers, in the discussion that follows.

Ullman's Concept of Spatial Interaction

Appropriately, the geographic example above is taken from the work of Edward L. Ullman, for it is his conception of the primary concern of geography, as the study of spatial interaction, that may be suggested as a most fruitful theoretical foundation for the geographic study of urban transportation.

According to Ullman, there are three concepts that together are sufficient to explain the interactions between any two areas: the first is complementarity, the lack of something in one area that the other can supply; the second is intervening opportunity, which must be absent, else the lack may be made up from this more convenient source; and the third

transferability, the sheer possibility of movement between the two areas taking place (1). It might be well to add a fourth concept, to take into account the action of the human will, which may disregard or change any or all of the other three. Since it may be peculiar to a given place or situation, perhaps we may call it idiosyncrasy.

These concepts are of direct relevance to the problem of urban transportation: in order for movement to take place between any two zones of a city, there must be complementarity between them; each must have something that the other needs; one may have workers, the other factories, one shoppers, the other stores. A newly created intervening opportunity may reduce the number of trips that formerly took place between two zones: for example, the building of a regional shopping centre may cause fewer shoppers to travel from a nearby suburban residential area to the downtown districts. Of most direct concern to transportation planners are transferability and idiosyncrasy: planners may do their best to make convenient movement between two areas possible, by providing mass transit services, and yet these may go relatively unused, as people continue to overload the city's roads with single-occupant cars.

For our purposes, then, the field of geography may be taken to be the study of spatial interaction, which in turn involves a careful examination of the way specific areas differ from each other, and of the forces that these differences generate, which result in movement between the areas.

General Remarks on Geographic Techniques

The two techniques of which geography has traditionally made the most intensive use are the making of field trips and the compilation of maps. Indeed, these two activities pretty well sum up the popular idea of what geographers do - or did while they still had the chance: they went out to explore unknown places, and came back with maps showing what they had seen. Of the two, it is the map that is most characteristic of geography:

> The Art of Biography
> Is different from Geography.
> Geography is about Maps,
> But Biography is about Chaps.

So says E.C. Bentley, and he is absolutely right.

But field trip and map cannot by themselves tell the whole story. To them must be added the facts that can be gained only by the gathering of statistical information and its analysis. And, as with any other science, once masses of facts about a great many areas and their interactions have been gathered, the difficult tasks of generalization and the formulation of meaningful concepts must be undertaken. In this process there is necessarily a great deal of borrowing from other disciplines, such as geology, meteorology, and geophysics; and, especially with respect to the study of the city and of transportation, from the sister social sciences of sociology, economics, and history.

In geography, as in all sciences, there has been a prodigious leap forward in the last ten years. The solid foundation of direct, empirical observation is still there, as is the painstaking gathering of facts. But there has

been evidenced an increasing sophistication in the analysis of these facts. Above all, a new school has emerged, the school of quantifiers, who are seeking to take advantage of recent advances in mathematical statistics, in operations research and linear programming, and in electronic computation, by use of which they hope to establish a set of geographic laws having a generality that has so far been impossible to achieve.

Application to Urban Problems

Internal Structure of the City

Some years ago the Wenner-Gren Foundation brought together a distinguished gathering of scientists and scholars, to discuss "Man's Role in Changing the Face of the Earth," of whom fully one third were geographers (2). As students of the face of the earth, geographers are of course very much interested in the way man changes it, and in no way does he change it so radically, or in so readily observable a form, as in the construction of cities. Therefore, geographers have for long directed their attention at the city itself, the complexity of its organization, and the way different parts of it take on different physical qualities that correspond with their different functions.

There is a vast literature devoted to describing the growth and functional zonation of individual cities, and over time the specific types of variations recurring in city after city have become recognized.

Too much attention need not be given here to this aspect of geographic work; all students of the city are

aware of its functional zonation, and how much of their knowledge is attributable to the work of geographers - or of sociologists - is to them of little significance.

Mention should be made, though, of the two types of study that have concentrated on the very edge and the very centre of the city, for in the interaction between these two parts of the city rise the most intractable of all problems in urban transportation.

The Rural-Urban Fringe. On the edge of the city occurs the conflict between antithetical types of land use, with blocks of houses and factories pushing suburban development out onto once rural acres. Representative of such studies is the much-admired work of Ralph R. Krueger, who has become the recognized authority on the fruitlands of the Niagara Peninsula in Ontario, where some of the most valuable of the scarce tender-fruit acreage of this continent is fast disappearing under houses (3). In the United States, a similar phenomenon is occuring on a much vaster scale in Southern California, and it has been made the subject of a special supplement of the Annals of the Association of American Geographers (4).

The Central Business District. Perhaps no single piece of geographic research has had so direct a bearing on all work on urban transportation as the study of the central business district by Murphy, Vance, and Epstein (5). Here, in a series of three papers, are presented exact quantitative methods for delimiting the C B D, a comparative study of C B D's in nine cities, and some conclusions about the inter-

nal structure of the C B D, based on the results of the comparative study (Fig. 3).

Murphy and Vance set themselves the essentially geographic task of defining a recognizably discrete region on the surface of the earth, a man-made region with characteristics of land use that are specific to it, and are repeated over and over again in the landscape. Most important, they determined to define the boundaries of that region in quantitative, objective terms, so that no matter who used the procedures they developed, the resulting conformation of the region should always be, within reasonably close tolerances, the same. They decided to use as the unit for describing this region, this central business district, not the lot, as had been usual before their time, but the whole city block. And the two criteria for measurement that they developed were the Central Business Height Index and the Central Business Intensity Index. The former is the number of floors devoted to the types of business characteristic of the central city, and is obtained by dividing the total floor area of all central business uses by the total ground floor area of the block. The latter is the percentage that the total floor area devoted to central business use makes up of the total floor space at all levels. Then they set up special rules by use of which they could designate entire blocks as being either in the central business district or outside it. They recognize the existence of a "core" area, an area that has since been intensively investigated by the engineer and urban planner, Edgar M. Horwood.

Horwood co-operated with a geographer, Ronald R. Boyce, in a program of studies that have materially advanced our understanding of the effect of urban freeways upon the city centre. The results of their investigations were first presented before the Highway Research Board in January of 1959 (6), and later the same year published in expanded form by the University of Washington Press (7). (See also (52).)

Dennis Durden and Duane F. Marble (8) have pointed out that, although planners of the C.B.D. have sought for a coherent body of ideas and concepts to provide perspective for their daily work, they have ignored theoretical developments in contemporary social science. They thereupon bring to the attention of planners a number of theoretical approaches from social science that the latter may find useful.

Location Theory. Economists are paying increasing attention to that aspect of their field that closely approaches the bounds of geography - the economics of location. Geographers have been happy to make use of the results of their labours, and location theory is becoming a recognized field of geographic study.

Building on the foundation laid by the German economist, August Lösch (9), they have developed new techniques and arrived at new theoretical concepts. Only a small part of location theory deals with the internal functional zonation of the city, but it is a most interesting part, and can lead to extraordinarily stimulating results. Take, for example, the map of a city, about which you know nothing more than

the distribution of population and of disposable income - nothing about the street pattern, about functional distributions, about residential areas, industry, commerce - and if on that map you can put, purely from theoretical considerations, exactly the right number of supermarkets, with each no more than a few hundred feet away from its actual location, then you have something worth paying attention to. This is exactly what the geographer Arthur Getis has been able to accomplish in his doctoral work on retail location in the city of Tacoma (53). If his results can be repeated for other cities, his technique should find ready application in urban transportation research.

External Relations of the City

The transportation needs of a city are determined not only by its own extent and the complexity of its own organization, but by the relation in which it stands to the surrounding countryside and to other cities. Indeed, its extent and complexity are themselves functions of its external relations; this is the subject of central place theory.

Central Place Hierarchy. What causes a city to become great? Why does it inexorably arrogate to itself a greater and greater concentration of a country's or a region's population, wealth, industry, and cultural life? In what relation do the lesser cities of the country or region stand to this great city, and to each other? And what of the still lesser cities, towns, and villages: why are they where they are, of the size that they are, offering the precise services that they do?

When all these questions are examined, a definite pattern begins to emerge, a pattern to which has been given the name "central place hierarchy."

The great city has been examined in such studies as Mark Jefferson's "The Law of the Primate City" (10), which stimulated much subsequent research - as, for example, by John Q. Stewart and William Warntz, who separately and together have subjected the pattern to mathematical analysis (11). By far the greatest impetus to the study of central places has come from the German geographer, Walter Christaller (12), who claimed to have discovered, in south Germany, a rigidly ordered hexagonal pattern (Fig. 4), to which he thought that the nested hierarchy of urban places everywhere would be found to conform. Further, there was not a gradual increase in population from the smallest place to the largest, but, instead, the places could be grouped in definite, discrete classes, and there were what we might call quantum jumps in population from class to class.

Christaller's work was first brought to the attention of American geographers by Edward Ullman (13). Much work has since been done to test the validity of Christaller's ideas, and the results, while they have in no case confirmed the rigidity of his ordering, have been fruitful in pointing out other, most suggestive, relations. Among the most interesting of such studies for our purposes are those from which our Figs. 5 and 6 have been taken, by A.K. Philbrick (14), (15). Philbrick has ranked the central places of the United States in an ascending series of orders, from first to seventh (Fig. 5). All places in the eastern United States from the fourth

order up, and the amount of railroad service each receives, are shown in Fig. 6. This schematic presentation allows us to see, with great clarity, how the amount of railroad service is related, not only to the ranking of each place, but to its spatial position, and emphasizes the density of the rail network in the area contiguous to Lake Michigan and Lake Erie.

The conglomeration of cities on the eastern seaboard has received special attention. It was a geographer, Jean Gottman, who borrowed the term "megalopolis" from the ancient Greeks to describe the coalescing of the spreading individual cities into this huge conglomeration (16). It was another geographer, Stephen B. Jones, who took a theoretical concept of Gottmann's and used it to reach what may be a most important insight about the city:

Gottmann, interested in the development of political entities, has suggested that they come into being through the action of two somewhat opposed forces, which in French he calls "circulation" and "iconographie." The first term refers to both transportation and the communication of ideas; the second describes the whole system of symbols in which a people believes. Circulation is (in part) a system of movement, iconography of resistance to movement. The one makes for change, the other for political stability.

Now, Jones suggests that

> many of the problems of a growing city arise from the fact that its circulation expands faster than its iconography. The metropolitan district outgrows the political limits, and vested local interests and loyalties make political expansion difficult. A sort of "metropolitan idea" may develop, leading usually to functional

> authorities rather than to political integration. There are a number of choices possible such as annexation of suburbs, city-county consolidation, metropolitan districts, functional authorities, state assumption of local functions.... (17).

Other concepts that have a bearing on the "metropolitan idea" are those of the "threshold" and the "range of a good," both of which have been given intensive study by Brian . . Berry and William Garrison (18),(19). The first deals with the size a city must achieve before it can support a given level of service, as, let us say, three doctors or five service stations; and the second, with the distance that people are willing to travel to purchase the good, whether a physical object or a service. In the application of these concepts to individual places a broad range of tools is brought into use: location theory and central place theory, the writings of Lösch and Christaller, the economic tools familiar to urban planners, such as the basic-non-basic concept and Leontief's input-output analysis; and this work in turn is used as the foundation for studies of urban transportation problems, as Berry (20) has done in his examination of ribbon development on the highway between Seattle and Everett (Fig. 5), and as he, Garrison and others have done more comprehensively in their book, Studies of Highway Development and Geographic Change (21).

Finally, there is the class of studies that groups cities in other ways, such as the functional classification by Chauncy D. Harris (22) and the service classification by Howard J. Nelson (23).

Quantitative Techniques

Although other geographers are making use of quantitative techniques of ever growing sophistication in attacking geographic problems, application of these techniques to urban transportation research is chiefly associated with two definite schools, that of the Swedish Royal University of Lund, and that of the University of Washington. Perhaps it would be more appropriate to call the latter after its leader, William Garrison, as Walter Isard has done; for most of its members, including Garrison himself, have moved to other universities in various parts of the United States.

Over the last decade the Lund school has produced an exceptionally interesting body of work, much of it based on rigorous mathematical analysis. Merely to list a few of the titles is to suggest the relevance of this work to urban transportation research: "Bus Services, Hinterlands, and the Location of Urban Settlements in Sweden" (24); "An Analysis of Automobile Frequencies in a Human Geographic Continuum" (25); "The Journey to Work from the Statistical Point of View" (26).

The school has been especially prolific in studies of migration, in which the journey to work, urban sprawl and commutation take a prominent place. Special mention must be made of the work of Torsten Hägerstrand, in whose "The Propagation of Innovation Waves" (27) and "Migration and Area" (28) original cartographic techniques are developed to help explain, respectively, the diffusion of (among other things) the ownership of motor vehicles among a population, and the

relation between the distance separating two places and the number of people migrating from place to place.

As for the Garrison school, we have already had occasion to refer to its pioneering work in location theory and on central place hierarchy. But these by no means exhaust its range. Members of the group have produced papers in which the latest tools of quantitative analysis - operations research, linear programming, regression analysis, simulation models, and graph theory - have all been put to use.

Cartographic Techniques

In urban transportation, time is of much more significance than distance. The maps with which we are familiar give us a just idea of the number of yards or miles between one point in a city and another, but are less exact in telling us about the number of minutes or hours it takes, under given conditions, to move between these points. Mathematical techniques have been developed, by such students as William W. Bunge Jr. (29), and Waldo R. Tobler (30), for constructing map projections that tell us about the time relations between points. Figs. 8 and 9 show what happens when such a projection is made. In Fig. 8 the shape and the street pattern of the city of Seattle are drawn to scale; at the peak travel hour, movement along some of the streets is faster than along others, so that the lines joining points of equal travel time are very irregular. In Fig. 9 these lines of equal travel time, or isochrones, have been smoothed out into concentric circles centering on the C B D, with a resulting distortion of the shape and street pattern of the city. The

areas nearest the C.B.D., where travel is slower, are shown as enlarged (taking up more space, as it were, in the time dimension), whereas those further away are foreshortened. It will be interesting to see what new distortions will be introduced by the north-south urban freeway now under construction.

Similar maps have been constructed to show cost-relations between points. The principles are exactly the same.

Map distortions can be used to highlight other urban relations. See, for example, what has happened to the shape of the world in Fig. 10. Though their total land area is four times that of the United States, in this map the Soviet Union, China and India together do not even equal the United States. Here at a glance is seen the relative importance in international trade of these four countries. Similar maps would be useful in emphasizing the internal relations of cities that have their effect on transportation, perhaps by eliminating such factors as topographic irregularities, or unevenness of population density, or differences in suitability for different types of land use, which themselves bring distortions to the transportation pattern.

Map distortions might be used in conjunction with still another new cartographic technique, the use of electronic computers in mapping, to which Tobler has given a great deal of attention. Graph theory can be used to describe the system of nodes and links that makes up a city's street network, and these can then be readily translated into computer language. The simple street pattern in Fig. 11A is topologi-

cally exactly equivalent to the seemingly more complex pattern in Fig. 11B, and the relations between the nodes and links of both are exactly reproduced in Fig. 11C. Now, since the topological equivalence is exact, no distortion of the shape of a city will affect its street network, as long as the pattern of nodes and links remains undisturbed. This procedure may find useful application in the setting up of a system of zones for Origin-Destination surveys, and the feeding of the necessary information into a computer.

The Commuting Problem

Mention has already been made of the Lund studies on the subjects of the journey to work and migration, both of which are aspects of the commuting problem. In Sweden great emphasis is placed upon bus service, and this emphasis is paralleled in other European countries, to a far greater extent than on this continent. Thus, we have the British geographers F.H.W. Green (31) and Robert E. Dickinson (32) using commuting by bus as a criterion for examining the relations between cities and their hinterlands in England and Germany respectively. Dickinson has further discussed the problem of commuting by all transportation media available in a German industrial area (33). German geographers too have studied the public transport system. Of unusual interest is a German study of the public transport system in Berlin before and after World War II (34). The destruction caused by war, the division into two sectors by a wall that has since become a physical fact, and the loss of many of the city's functions, have caused a shift in vitality from the central

to the peripheral areas of Berlin. This shift is well illustrated in two traffic flow plans: whereas before the war the usual pattern obtained, of heavy traffic in the city centre becoming progressively lighter as the outskirts are approached, after the war the pattern was reversed, and the heavier traffic is now found away from the central area. Studies such as this might well be brought to the attention of people working on civil defence plans.

On this continent, geographic work on mass transit is conspicuously meagre. To be sure, there is a study on streetcar traffic, which appeared as long ago as 1917 (35), and which has the added interest of being the only paper I have seen that discusses climatic effects on urban transportation from a geographic point of view. And there is, finally, a paper by James E. Vance, Jr. (36), from which our Fig. 4 is taken, that may turn out to be one of the most influential in the field of urban transportation geography - as influential, let us say, as the above-mentioned series on the C B D, with which Vance was also involved. Vance uses what he calls "dynamic analysis", a stage-by-stage comparison of various conditions over time, to discover the effect of the changing technology of transportation on sources of labour supply, on the journey to work, on the shape of the city, and on its relations with satellites and suburbs. He makes the value of his work to planners explicit by discussing the application of his findings to the problems of urban planning.

Miscellaneous Transportation Studies

Waterways, railways, and airways have all received attention from geographers, but no very great proportion of their work has any direct relevance to urban transportation research. Indirectly, of course, almost any study of transportation has its bearing on cities, which are nodal points in all transportation networks.

Chicago, as a great transportation centre, has received a commensurately detailed examination from this point of view. Representative studies that may be mentioned are those by Harold M. Mayer on Chicago's relation to the St. Lawrence Seaway (37) and on its railway facilities (38); and by Edward J. Taaffe on its air passenger hinterland (39). On ports in general, Weigend is among the chief authorities (40); and, though he restricts himself to European cities, Beaver (41) has some valuable comments to make on railway patterns near and within great cities.

We have already referred to many geographic studies of the transportation facilities that are of most immediate concern to the city, its streets and highways, and our next section will offer further discussion of them. But we may round out the present catalogue of transportation studies by adding two that deal respectively with highways on the outskirts of cities and the streets within. The first, by Andreas Grotewold (42), examines one of the most difficult problems that highway planners have to contend with: the proliferation, on the high-

ways passing through the rural-urban fringe, of commercial establishments that adversely affect the quality of traffic flow. The second, by John R. Borchert (43), uses the density of the street network in an urbanized area - the number of street and road intersections per square mile - not only to discover the pattern of development in the past and in the present, but to extrapolate that development into the future.

Geographers have been just as prone as other students of transportation to concentrate their attention on one or two transportation media, but with less excuse. As practitioners of a discipline that is, in its essence, an integrative and correlating discipline, they might have been expected to approach, (or, as Vance would prefer, attack) the problem of transportation, and particularly of urban transportation, on all its manifold fronts. Fortunately, geographers are becoming no less concerned than other scientists give evidence of becoming, over the fragmentation that has so far characterized their work on transportation, and we may expect to see many more studies, such as that by Vance, that examine urban transportation as a whole.

Geography and the Highway Research Board

Only within the last five years have highway planners been given the direct opportunity, at the meetings and in the publications of the Highway Research Board, of learning what

geographers have been doing in their field. Although in all the highway departments of the United States there are only two geographers permanently employed, others have from time to time been brought in as consultants, or have served on such bodies as the Twin Cities Area Transportation Study, two of whose four top positions were occupied by geographers. Much more numerous are geographers associated with urban planning boards. But by far the greatest amount of geographic research on the city and on transportation is done in the universities.

The papers that geographers have presented before the Highway Research Board in the period beginning in 1957, when the first one appeared, have necessarily had a direct bearing on the interests of practicing planners, though in fact all but one of them were prepared by academic geographers. The exception was the very first to appear, which was presented by two geographers on the staff of a Canadian highway department, in conjunction with a highway engineer, on the subject of highway classification techniques (44).

The two state highway departments that have had the closest association with geographers in the universities have been those of Washington and Minnesota. These departments have collaborated with the Bureau of Public Roads and the state universities in conducting many economic impact studies, which have resulted in the publication of numerous papers under the joint auspices of all the bodies involved, among them such papers as that by Garrison and Marts on the influence of highway improvements on urban land (in Washing-

ton) (45), and by Borchert on commercial-industrial development along highways in the Minneapolis-St. Paul area (46).

The Highway Research Board has been informed of some of the results of this research, e.g. in a paper from Washington on application of linear programming techniques to analysis of highway networks (47), and one from Minnesota on the Twin Cities Study (48).

Only one paper to the Highway Research Board has been presented by a geographer who was not in any way involved with practical planning, but it was perhaps the most significant of all (49). For in it Raymond E. Murphy brought to the attention of highway workers the very important insights that, as we have seen, he and his colleagues have brought to the study of the central business district.

Thus, a beginning has been made towards acquainting highway workers with the results of geographic research on the city and on transportation problems.

Students' Theses

One last source of information must be mentioned, but this is perhaps the most valuable to local planners. Students preparing for undergraduate and graduate degrees are frequently assigned problems in urban and transportation research, and sometimes their reports contain information of the greatest value. Geography departments in universities across the continent have great numbers of such reports, in the form of bachelor's, master's, and doctoral theses, which, because they are unpublished, seldom come to public attention, but which in many cases are well worth consulting. The map in

Fig 12 comes from just such a thesis (50), and helped planners to familiarize themselves with the physiographic problems that had to be solved in laying out the future street and highway network of the city shown. We in Ontario make constant use of geographic theses prepared in universities throughout Canada and even abroad. Most assuredly, planners elsewhere can gain equal value from research done by university students on the cities in which those planners are interested.

Interdisciplinary Co-operation.

In the planning of transportation facilities for cities, voices from many disciplines must be heard, but it is the engineer who must have the last word, for his is the ultimate responsibility of providing the physical facilities themselves. Appropriately, therefore, the last words in the present paper will be given to two engineers, both eminent leaders in transportation research.

In his foreword to a report on the Woods Hole Conference on Transportation Research, Harmer E. Davis wrote:

> Transportation affects, and is affected by, many economic, social and institutional factors. The competence of those engaged in the engineering and the physical sciences can be brought to bear on only a few of the aspects that are involved in the functioning of transport. It was recognized at the outset of this undertaking that adequate appraisal of the transportation situation would require the insights not only of the engineers and physical scientists, but also social scientists, economists, urban planners, lawyers, and others intimately familiar with the practical aspects of providing transport facilities and operating the services..... (51).

And here, from a personal communication written by John C. Kohl, are the words that best end this paper:

.... [There is a need to] reinforce the currently hesitant approach by our own geographers who are lacking in conviction about their role in transportation planning. As a transportation engineer, I have long felt the need for geographers in planning activities.....

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APPENDIX

Bibliographical Material

The fields of both urban and transportation geography are advancing so rapidly that bibliographies and collections of articles, no matter how painstakingly compiled, rapidly become out of date. Nonetheless, the book of readings in urban geography edited by Mayer and Kohn, in which many of the items referred to in the present paper are included (see note appended to the list of references, above), remains valuable, in that it gives an overview of the whole field of urban geography. The fact that no articles on urban street and highway problems are included indicates how recently these problems began to attract the attention of geographers.

For the relation of urban and transportation geography to the field of geography as a whole, see "American Geography: Inventory and Prospect", edited by Preston E. James and Clarence F. Jones (Syracuse University Press, 1954). This compilation was published five years earlier than the book edited by Mayer and Kohn, and is due for revision. Still, it retains the permanent value inherent in any undertaking on which a group of first rate authorities have co-operated.

Geographers depend to a very high degree on work performed in disciplines other than their own. The catholicity of their reading is illustrated in "An Annotated Bibliography of the Geography of Transportation", the largest part of which deals with urban transportation, compiled in 1961 by the author, with the help of Miss Beverly Hickok, Librarian of the Institute of Transportation and Traffic Engineering,

University of California at Berkeley, and issued by the Institute as Information Circular No. 29.

More specialized, but still covering other disciplines besides geography, are a number of bibliographic studies conducted by Berry and by Garrison. The most ambitious of these is "Central Place Studies: A Bibliography of Theory and Applications", compiled by Brian J.L. Berry and Allen Pred (Bibliography Series, No. 1; Regional Science Research Institute, Philadelphia, 1961). Berry has also published a paper on "Recent Studies Concerning the Role of Transportation in the Space Economy", (Annals, Association of American Geographers, 1959, pp. 328-342). And William L. Garrison surveyed the literature on "Spatial Structure of the Economy" in a series of three papers, also in the Annals, pp. 232-239, 471-482 (1959) and 357-373 (1960).

Finally, an invaluable source of bibliographical information ~~that~~ for all who are interested in the whole field of location and central place theory, in simulation models (especially the gravity model) and other quantitative techniques, ~~will find the references listed in~~ Walter Isard's "Methods of Regional Analysis" ~~invaluable~~ (The Technology Press of M.I.T. and John Wiley & Sons, New York, 1960).

FIGURE CAPTIONS

1. The information about traffic flow shown here is used by engineers to help provide efficient facilities for movement. (From "A Highway Plan for the Hamilton-Wentworth Area", Department of Highways Ontario, Toronto, 1961)

2. The information about commodity flow shown helps geographers to gauge the spatial interaction between areas. (From Ullman (1).)

3. The city blocks that make up the C.B.D. are specified according to the levels reached by their Central Business Height Index and Central Business Intensity Index, as defined in the text. (From Murphy and Vance (5).)

4. Christaller's hexagons are here used to help lay a theoretical foundation for an empirical study of the effects of changing technology of transportation on urban hinterlands. (From Vance (36).)

5. The nested hierarchy of central places schematically shown. (From Philbrick (14).)

6. The external transportation needs of cities are conditioned by the relations between these cities and others in the hierarchy of central places. (From Philbrick (15).)

7. The problem of ribbon development along highways on the outskirts of towns and cities is related to those of urban sprawl and of premature obsolescence of highways. (From Berry (20).)

8. This map, together with that in Fig. 9, illustrates a possible application of cartographic techniques of distortion to urban time-distance studies. (From Tobler (30).)

9. See Fig. 8.

10. Map distortions can be used to highlight urban relations in a manner similar to that in which world relations in international trade are highlighted here. (From Andreas Grotewold, "Some Aspects of the Geography of International Trade." Economic Geography, October, 1961, p. 314.)

11. Graph theory, when used in conjunction with map distortions, can facilitate use of electronic computers in mapping transportation networks. As long as the connections between nodes and links remain the same, the shape of the map may be changed at will. (After Bunge (29).)

12. Undergraduate and graduate theses are sources of invaluable regional information. The map here shown helped transportation planners understand the physiographic problems they had to solve. (From same source as Fig. 1; after Westland (50).)

FIG. 1


HAMILTON
SCALE OF MILES
0 2 4 6 10
TRAFFIC FLOW
on
KING'S HIGHWAYS
1957
20,000
5000
500
A.A.D.T.
2000
10,000
• A HIGHWAY PLAN FOR THE HAMILTON – WENTWORTH AREA •

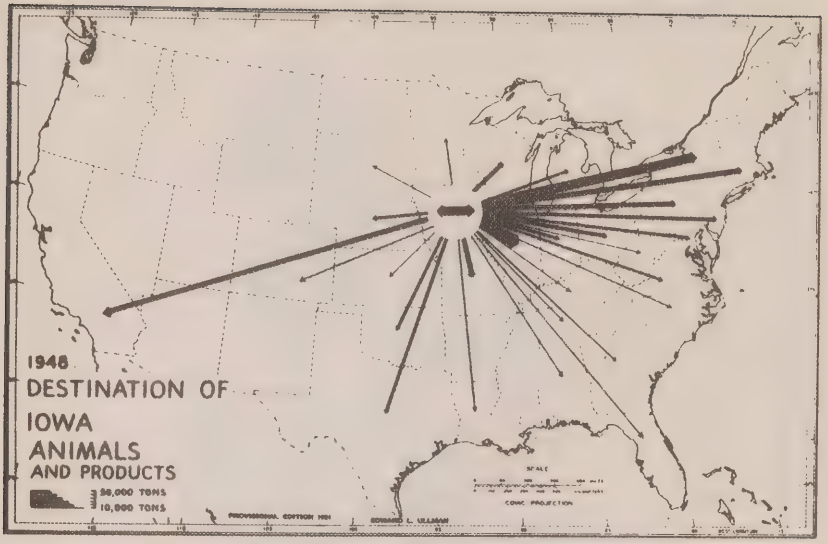

1948
DESTINATION OF
IOWA
ANIMALS
AND PRODUCTS
50,000 TONS
10,000 TONS

FIG. 2

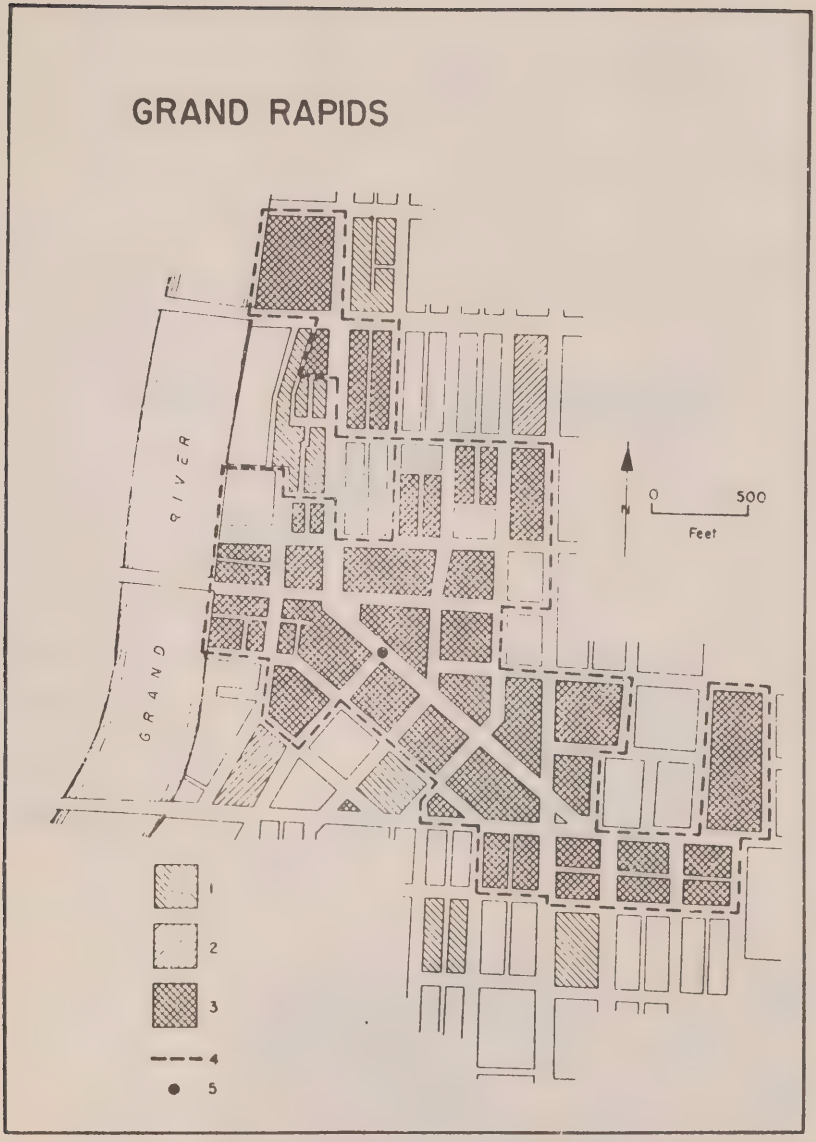


FIG. 7. Irregularity in shape characterizes the Grand Rapids CBD. The district extends in a roughly NW-SE direction, with its peak land values where Market Avenue, coming from the southwest, forms a T intersection with NW-SE trending Monroe Avenue. Grand River on the west and a steep rise toward the east help to account for the overall shape of the district. As in Worcester there is a great range in block sizes.

Key to legend: 1. Central Business Height Index of 1 or more; 2. Central Business Intensity Index of 50 or more; 3. Central Business Height Index of 1 or more and Central Business Intensity Index of 50 or more; 4. CBD boundary; 5. Peak land value intersection.

FIG. 3

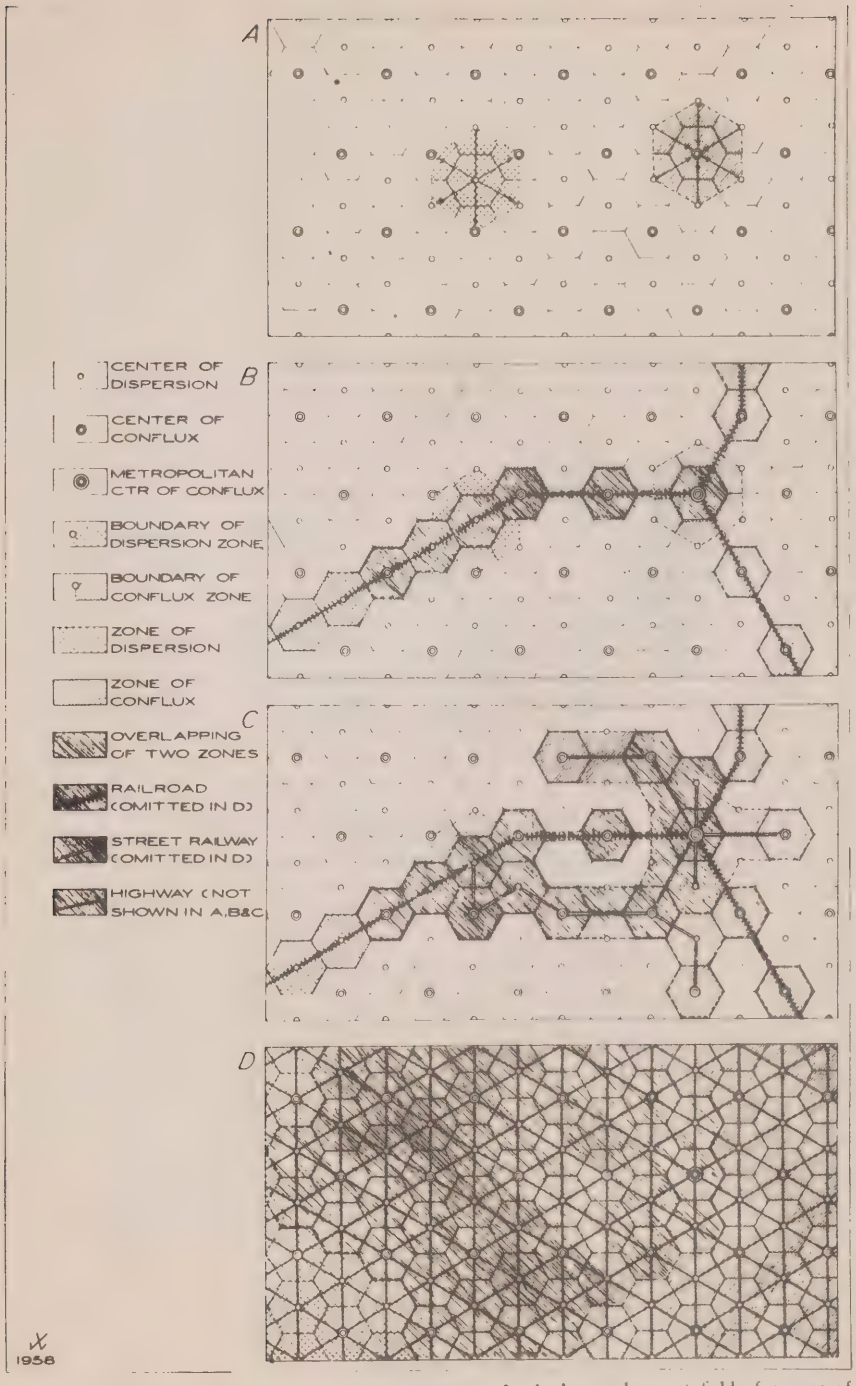
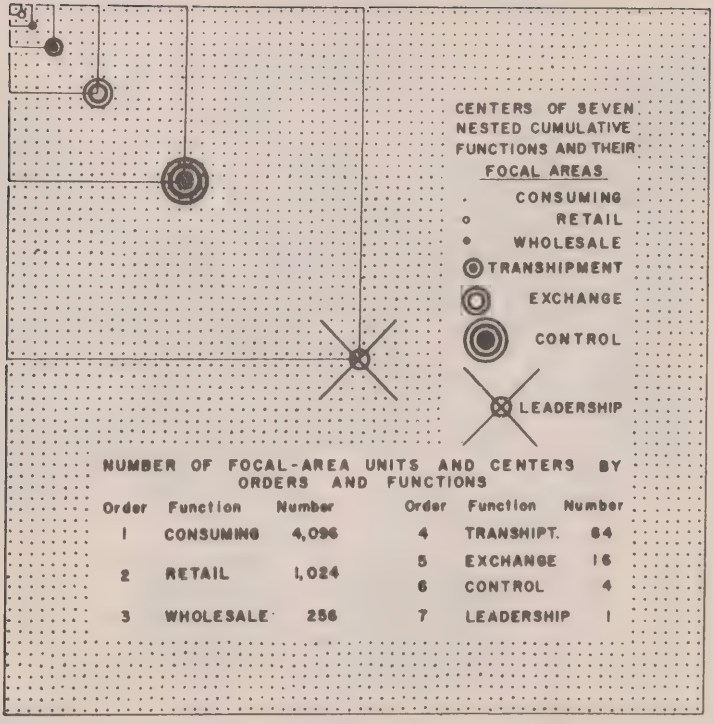


FIG. 2. The model. Growth of the zones is shown. In A the employment field of a zone of dispersion and the labor-shed of a zone of conflux appear as theorized under the influence of pedestrial commutation. In B the railroad is introduced and the growth of the employment field and labor-shed shown. In C the street railway is added. In D the ultimate "filling out" of the employment field and labor-shed is tied to the introduction of automobile commutation.

FIG. 4



NUMBER OF FOCAL-AREA UNITS AND CENTERS BY ORDERS AND FUNCTIONS

Order	Function	Number	Order	Function	Number
1	CONSUMING	4,096	4	TRANSHIPT.	64
2	RETAIL	1,024	5	EXCHANGE	16
			6	CONTROL	4
3	WHOLESALE	256	7	LEADERSHIP	1

FIG. 5

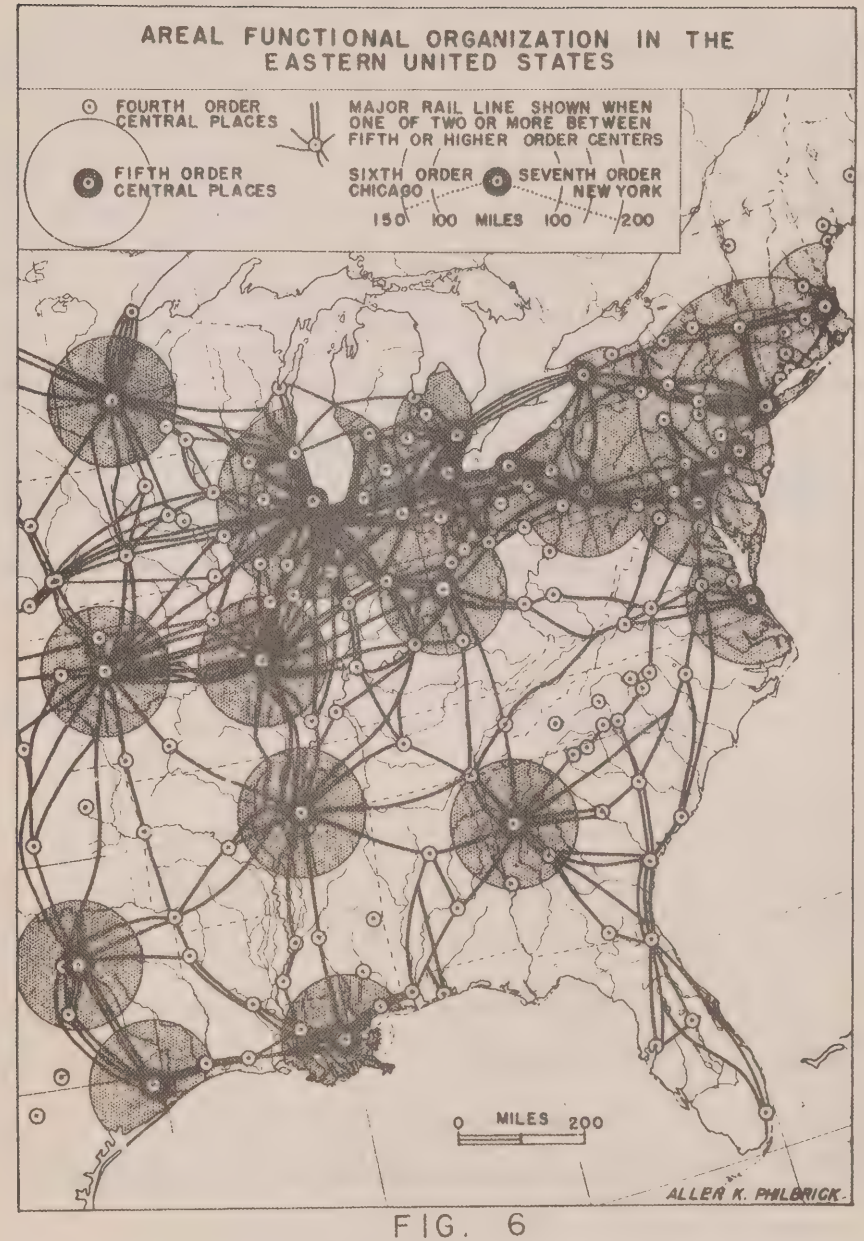

AREAL FUNCTIONAL ORGANIZATION IN THE EASTERN UNITED STATES
FOURTH ORDER CENTRAL PLACES
FIFTH ORDER CENTRAL PLACES
MAJOR RAIL LINE SHOWN WHEN ONE OF TWO OR MORE BETWEEN FIFTH OR HIGHER ORDER CENTERS
SIXTH ORDER CHICAGO
SEVENTH ORDER NEW YORK
150 100 MILES 100 200
0 MILES 200
ALLER K. PHILBRICK

FIG. 6

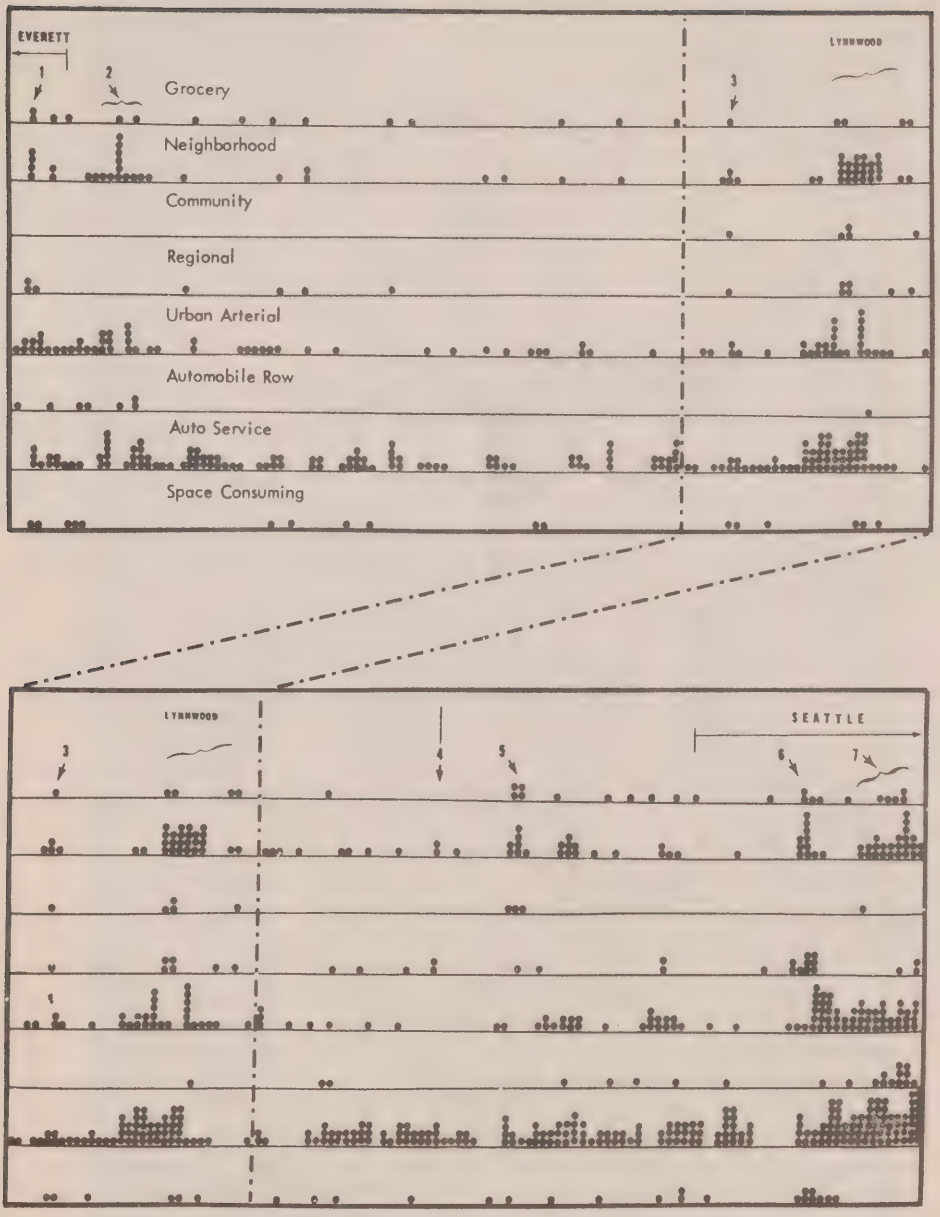
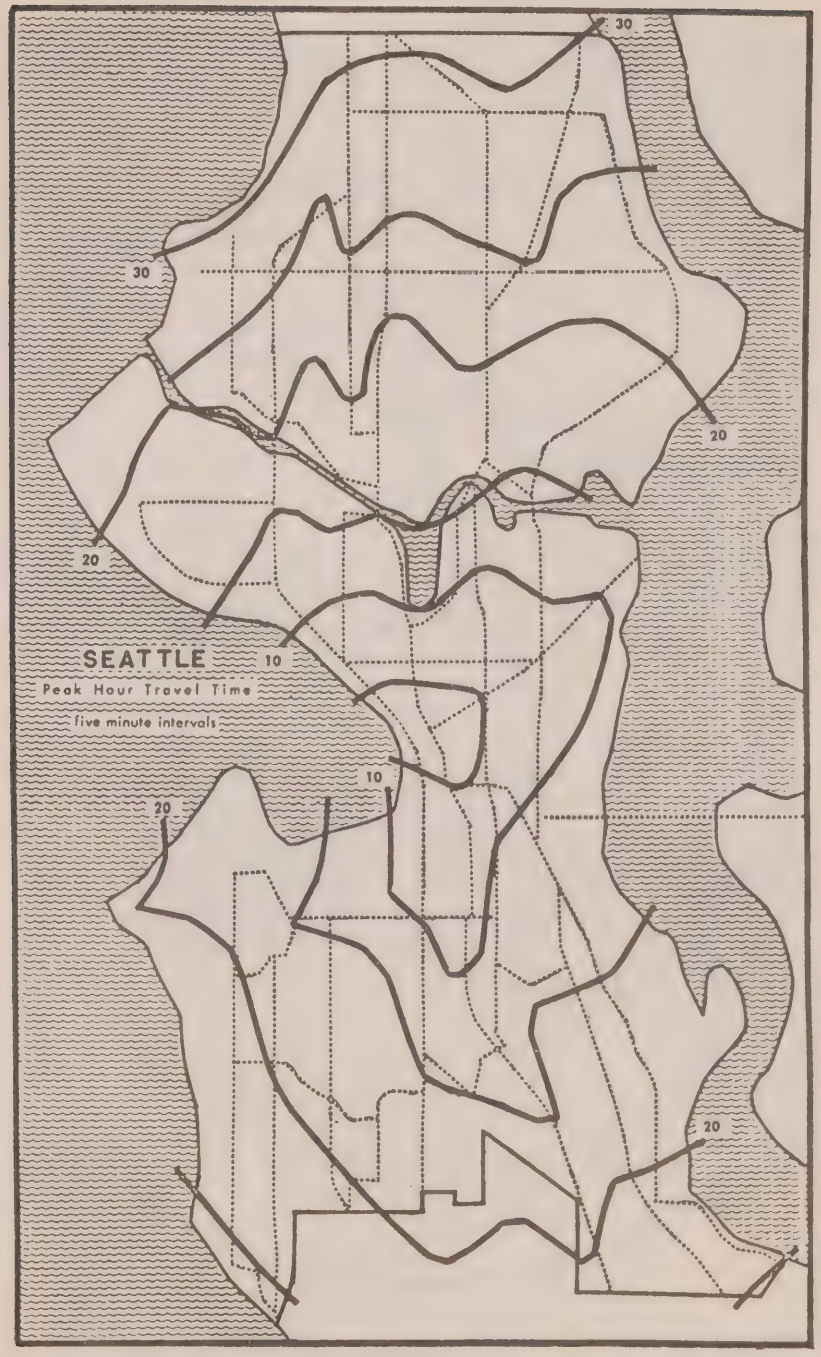


FIG. 6. Distribution of business types within groups in successive eighth-mile annules along U. S. Highway 99. One dot represents one business establishment, plotted by occurrence in the eighth-mile annule regardless of side. Note how the two parts of the figure overlap around Lynnwood. At top left, data are available within the city limits of Everett; at bottom right they extend into Seattle. Nucleations identified by number are as follows: 1, B and M; 2, Safeway; 3, Sno-King Drive-In; 4, Snohomish County-King County Line (also known as Sno-King); 5, Richland Highlands; 6, unnamed, North Seattle; 7, Green Lake. These data were collected in the field by Mr. Alexious Shakar.

FIG. 7

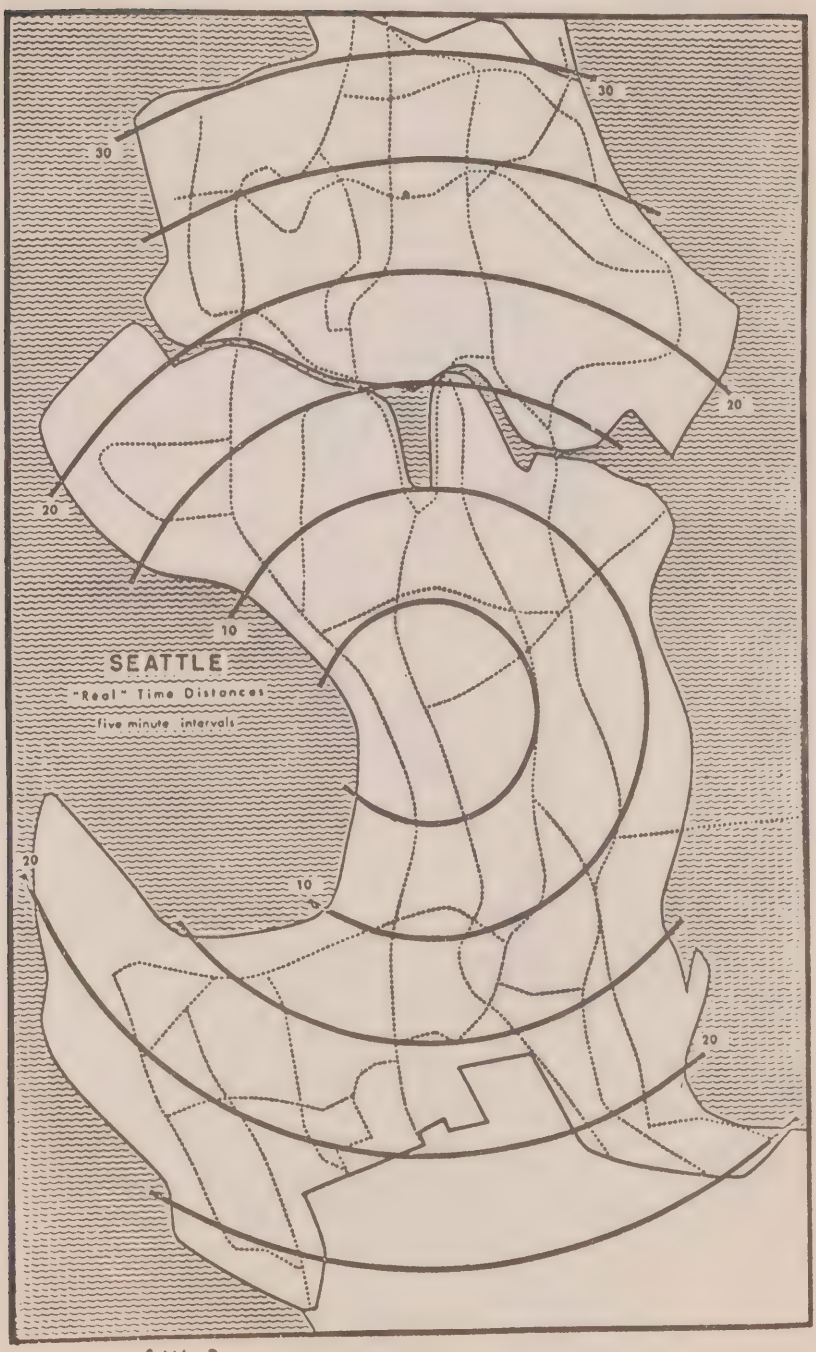
SEATTLE ISOCHRONES



Courtesy of W. Bunge

FIG. 8

SEATTLE - TIME DISTANCES FROM CBD



Courtesy of W. Bunge

FIG. 9

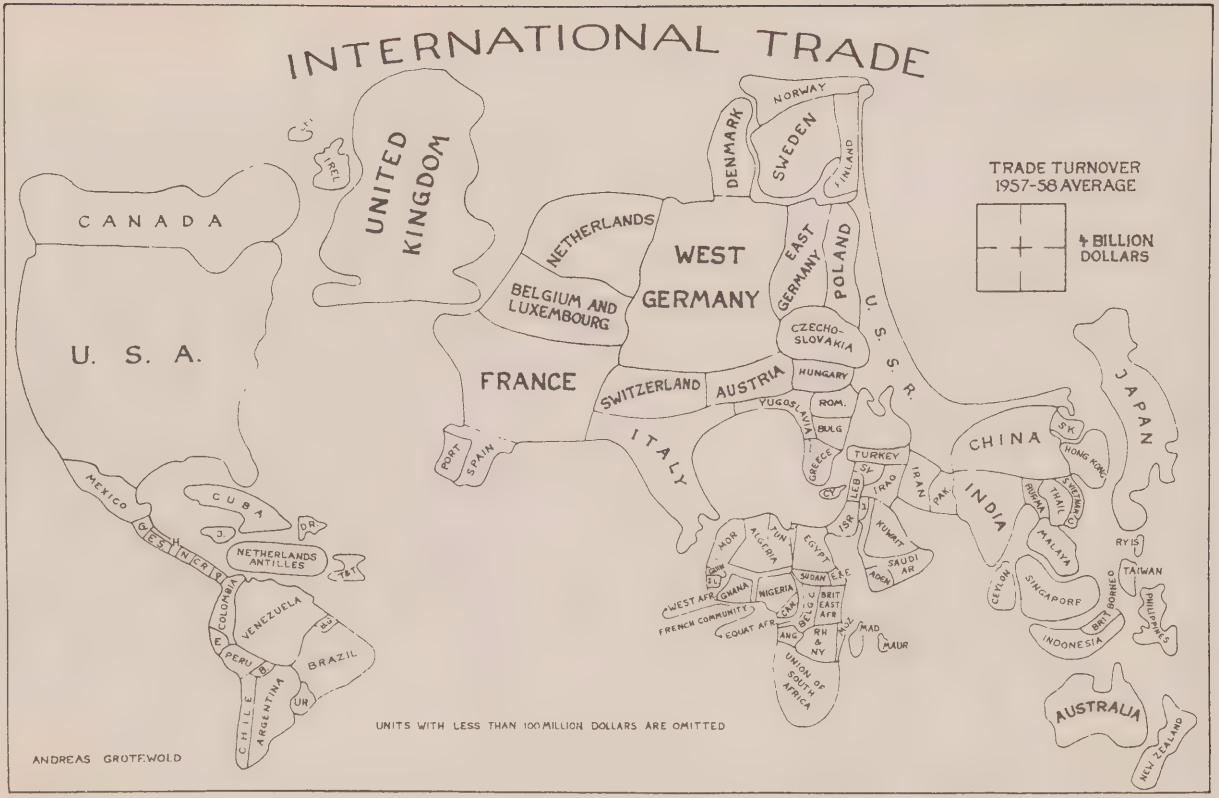
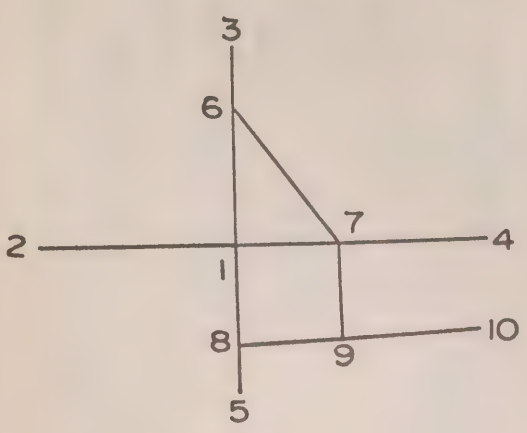

INTERNATIONAL TRADE
TRADE TURNOVER
1957-58 AVERAGE
4 BILLION
DOLLARS
CANADA
U. S. A.
UNITED KINGDOM
IRELAND
NETHERLANDS
BELGIUM AND LUXEMBOURG
WEST GERMANY
EAST GERMANY
POLAND
DENMARK
NORWAY
SWEDEN
FINLAND
U. S. S. R.
CZECHO-SLOVAKIA
HUNGARY
FRANCE
SWITZERLAND
AUSTRIA
YUGOSLAVIA
ROM.
BULG.
GREECE
TURKEY
ITALY
PORT.
SPAIN
CHINA
JAPAN
HONG KONG
INDIA
PAK.
IRAN
IRAQ
KUWAIT
SAUDI AR.
ADEN
MALAYA
SINGAPORE
INDONESIA
BRIT. BORNEO
PHILIPPINES
TAIWAN
AUSTRALIA
NEW ZEALAND
MEXICO
CUBA
NETHERLANDS ANTILLES
VENEZUELA
COLOMBIA
PERU
BRAZIL
CHILE
ARGENTINA
ALGERIA
EGYPT
NIGERIA
GHANA
WEST AFR.
FRENCH COMMUNITY
EQUAT. AFR.
BRIT. EAST AFR.
UNION OF SOUTH AFRICA
UNITS WITH LESS THAN 100 MILLION DOLLARS ARE OMITTED
ANDREAS GROTE.WOLD

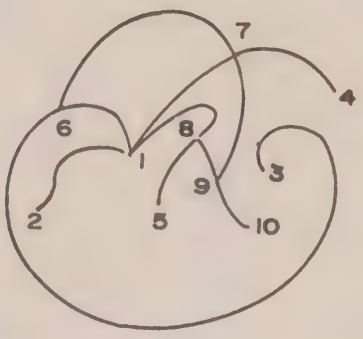
FIG. 10

GRAPH THEORY

TOPOLOGICALLY EQUIVALENT LINKAGES.



A



B

	1	2	3	4	5	6	7	8	9	10
1		1				1	1	1		
2	1									
3						1				
4							1			
5								1		
6	1		1				1			
7	1			1		1			1	
8	1				1				1	
9							1	1		1
10									1	

C

After Wm. Bunge.

FIG. 11

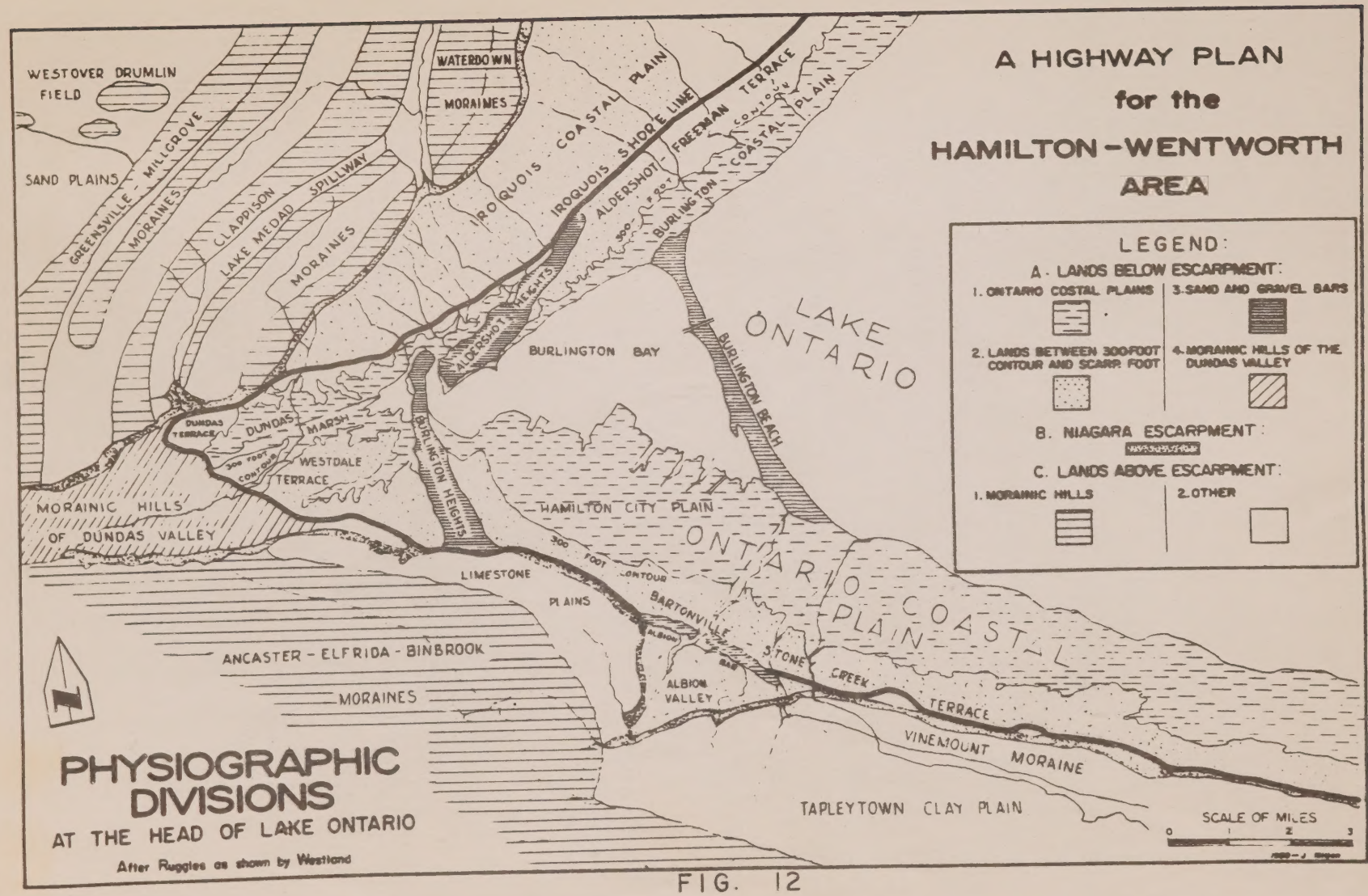

A HIGHWAY PLAN
for the
HAMILTON-WENTWORTH
AREA
LEGEND:
A. LANDS BELOW ESCARPMENT:
1. ONTARIO COSTAL PLAINS
2. LANDS BETWEEN 300-FOOT CONTOUR AND SCARP FOOT
3. SAND AND GRAVEL BARS
4. MORAINIC HILLS OF THE DUNDAS VALLEY
B. NIAGARA ESCARPMENT:
C. LANDS ABOVE ESCARPMENT:
1. MORAINIC HILLS
2. OTHER
WESTOVER DRUMLIN FIELD
SAND PLAINS
GREENSVILLE - MILLGROVE MORAINES
CLAPPISON LAKE MEDAD SPILLWAY
MORAINES
WATERDOWN MORAINES
IROQUOIS COASTAL PLAIN
IROQUOIS SHORE LINE
FREEMAN TERRACE
COMINGTON COASTAL PLAIN
ALDERSHOT
BURLINGTON
300-FOOT
ALDERSHOT HEIGHTS
BURLINGTON BAY
LAKE ONTARIO
BURLINGTON BEACH
DUNDAS TERRACE
DUNDAS MARSH
300 FOOT CONTOUR
WESTDALE TERRACE
BURLINGTON HEIGHTS
MORAINIC HILLS OF DUNDAS VALLEY
HAMILTON CITY PLAIN
ONTARIO COASTAL PLAIN
300 FOOT CONTOUR
LIMESTONE PLAINS
BARTONVILLE
ALBION FALLS
ALBION VALLEY
STONE CREEK
TERRACE
VINEMOUNT MORAINE
ANCASTER - ELFRIDA - BINBROOK MORAINES
TAPLEYTOWN CLAY PLAIN
SCALE OF MILES
0 1 2 3
PHYSIOGRAPHIC DIVISIONS
AT THE HEAD OF LAKE ONTARIO
After Ruggles as shown by Westland

FIG. 12